ORIGINAL

LAWLER, METZGER & MILKMAN, LLC

1909 K STREET, NW
SUITE 820
WASHINGTON, D.C. 20006

PHONE (202) 777-7700
FACSIMILE (202) 777-7763

EX PARTE OR LATE FILED

December 16, 1999

RECEIVED

DEC 16 1999

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

BY HAND

Magalie Roman Salas, Secretary
Federal Communications Commission
445 Twelfth Street, S.W. - Suite TW-A325
Washington, D.C. 20554

Re: WT Docket No. 99-168 and WT Docket No. 96-86
Written Ex Parte Presentation

Dear Ms. Salas:

Transmitted herewith are four copies of a written *ex parte* presentation by FreeSpace Communications (FreeSpace) for inclusion in the public record of the two above-referenced proceedings. In WT Docket No. 99-168, FreeSpace has proposed that the Commission establish guard bands adjacent to the public safety bands and to require commercial services operating in these guard bands to comply with technical rules to protect public safety communications from interference. FreeSpace has agreed to comply with the technical rules -- including frequency coordination procedures, power limits, and out-of-band emissions limits -- that Motorola, Inc. has proposed for users of the guard bands, or any other rules the Commission or the public safety community deem to be appropriate.

In addition to frequency coordination and power limit requirements, commercial services operating in the guard bands must comply with strict out-of-band emissions limits to protect public safety systems. The attached memo provides a detailed technical analysis of the required adjacent band attenuation to provide complete protection to public safety mobile receivers. The analysis shows that attenuating adjacent band emissions, as measured in a 6.25kHz bandwidth, by 84+10logP dB below the full-bandwidth transmitter power would be sufficient to protect public safety units from interference. In this formula, P is the full-bandwidth transmit power in watts. This would result in an interference power at the input of the transmit antenna of no more than –54dBm in a 6.25kHz bandwidth. This is within 3dB of the -57dBm limit proposed by Motorola. (*See* Letter of Leigh Chinitz, Motorola, Inc. to Magalie Roman Salas, WT Docket No. 99-168 (filed Dec. 2, 1999).) FreeSpace therefore would support the adoption of Motorola's proposal of a -57dBm limit, or, equivalently, a requirement that a guard band licensee attenuate its out-of-band emissions by a factor of not less than 87 +10 log (P) in a 6.25 kHz bandwidth.

No. of Copies rec'd 0+4
List ABCDE
O+3

The attached analysis is very similar to the analysis FreeSpace submitted to the Commission on November 24, 1999. The November 24 filing determined that an attenuation of 68dB below the proposed transmit power spectral density limit of 4mW/kHz was required for base units operating in the guard band adjacent to the public safety mobile receive band, resulting in an interference power into the transmitter antenna of no more than –54dBm in a 6.25kHz bandwidth. Based on this result, FreeSpace recommended specific out-of-band emissions limits to the Commission and provided a formula for calculating the required attenuation based on transmitter power.

The attached memo uses the same analysis set forth FreeSpace's November 24 filing, but is revised to take into account the assumptions underlying a set of draft rules recently proposed by Motorola. (*See* Letter of Steve Sharkey, Motorola, Inc., WT Docket Nos. 99-169 & 96-86 (filed Dec. 13, 1999).) In particular, the attached memo sets forth the formula for required attenuation so that it can be interpreted under the same assumptions as the proposed draft rules. We emphasize that our analysis has not changed; we have only modified the manner in which we express that analysis in X + 10 log P form so that is its consistent with the assumptions underlying Motorola's proposed rules.

Sincerely,

Charles W. Logan

Charles W. Logan

Enclosure

cc:

Ari Fitzgerald	Mark Schneider
Bryan Tramont	Peter Tenhula
Adam Krinsky	Dale Hatfield
Julius Knapp	Thomas Sugrue
James Schlichting	Kris Monteith
Marty Liebman	Jay Jackson
Herbert Zeiler	Kathleen Wallman
Michael Wilhelm	

FREESPACE COMMUNICATIONS

A Technical Analysis of Necessary Adjacent Band Attenuation

There are a number of proposals before the Commission about the out-of-band spurious emissions limits necessary to provide adequate interference protection for public safety units that will operate in the 764 – 776MHz and 794 – 806MHz bands. FreeSpace Communications (FreeSpace) submits this technical filing to propose specific emissions limits that it believes, as set forth in the analysis below, will provide protection to public safety operations. FreeSpace is committed to ensuring that commercial services operating in guard bands adjacent to the public safety bands provide full protection against interference to public safety communications. We support the FCC's adoption of technical rules, including strong limits on out-of-band emissions, that are necessary to accomplish this objective. As a licensee of these guard bands, FreeSpace would of course comply with any rules the FCC requires to protect public safety.

For our analysis, FreeSpace assumes the following conservative requirements to protect public safety mobiles and bases:

- Interference introduced into the public safety band should be at least 6dB below the noise floor of a typical public safety receiver.
- A typical public safety receiver has a noise figure of 8dB.
- There should be a very high confidence level that there be no interference to public safety receivers.

To meet the established emission limits in public safety spectrum, manufacturers should be required to demonstrate a specified attenuation of adjacent band spurious emissions (adjacent band attenuation, or *ABA*) at the interface to public safety spectrum. In adopting an approach for evaluating the necessary *ABA*, it is important to consider a method that is robust for the real-world propagation of radio-frequency signals. Therefore, this paper presents an analytical framework that is physically reasonable and as accurate as the uncertain radio environment will permit. In particular, FreeSpace adopts the following criteria:

- The analytical framework should be *physically reasonable* and as accurate as possible, given the unavoidable uncertainty of the radio environment.
- A primary concern is the probability that a fixed or mobile unit will experience interference under the adopted rules. Thus, the analytical framework should permit the specification of a *high confidence level that no interference will occur.*
- Radio propagation is difficult to predict due to the presence of multipath, ground reflections and attenuation by buildings, trees, etc. Thus, the analytical framework should support the specification of *margins* to guard against variations in propagation conditions. Furthermore, the framework should accommodate the use of the propagation model that leads to the adoption of *conservative requirements*.

In the following section, FreeSpace outlines a framework that meets the above goals and provides clear guidance on the selection of an appropriate *ABA* specification. A detailed discussion and mathematical derivation of the resulting formula for *ABA* is provided in the Appendix.

A Methodology for Determining Adjacent Band Attenuation Requirements

The transmit power and adjacent band attenuation of a transmitter are two factors that determine the radius at which a victimized mobile receiver from a neighboring system will experience interference. The transmit power also determines the coverage area of a cell, and thus the number of cells that are deployed. So, each cell produces its own interference region, and the probability that a victim mobile will wander into one of these regions is given by the ratio of the total area of all interference regions to the coverage area of the cellular system.

It is important to note that a potential victim becomes less susceptible to interference as it moves closer to its own base station. However, without knowing the relative positions of the base stations in the two systems, it is difficult to account for this effect. Thus, *a conservative analysis assumes that, regardless of position, the victim mobile must be able to operate at maximum sensitivity.* This simplification makes it possible to define a radius of interference that is the same for all cells, regardless of how close that cell is to the victim mobile's base station.

In particular, the area of the interference region is related to the following quantities:

- P_T – the transmit power of the interfering transmitter.
- ABA – the adjacent band attenuation of the interfering transmitter.
- G_T – the antenna gain of the interfering transmitter.
- G_V – the antenna gain of the victimized receiver.
- F_V – the noise figure of the victimized receiver.
- M_I – the interference margin, which determines the probability of interference at the boundary of the interference region.

Similarly, the coverage area of the interfering system is related to these quantities:

- P_T – the transmit power of the interfering transmitter.
- G_T – the antenna gain of the interfering transmitter.
- G_R – the antenna gain of the related receiver.
- F_R – the noise figure of the related receiver.
- $SNR_{\min}$ – the minimum signal-to-noise ratio for the related receiver.
- M_R – the receiver margin, which determines the probability of reception at the boundary of the cell.
- η – the degree of cell overlap.

It is straightforward to develop expressions for both the coverage and interference areas. The ratio of the areas then provides a *conservative* estimate of the probability of interference, or alternatively the confidence level that no interference will occur. The estimate is conservative because the victimized mobile receiver is assumed to be in a state of maximum sensitivity to interference, regardless of its position. In reality, this is not the case. Qualitatively, one can think of the confidence level as being *the probability that no interference will occur for victim mobiles operating near the boundary of their own coverage region.* Obviously, the further inside its own coverage area a victim receiver is, the greater the confidence level that no interference will occur.

Pursuing this approach, one can then solve for the required adjacent band attenuation in terms of the engineering quantities noted above. The resulting expression for adjacent band attenuation is

$$ABA = M_I M_R SNR_{\min} \frac{F_R}{F_V} \frac{G_V}{G_R} \left[\frac{\eta}{1-CL} \right]^{N/2},$$

where M_I is the interference margin, M_R is the reception margin, $SNR_{\min}$ is the minimum signal-to-noise ratio required for reception in the interfering system, F_R is the receiver noise figure, F_V is the noise figure of the victimized receiver, G_V is the antenna gain of the victimized receiver, G_R is the antenna gain of the interfering system's receiver, η is the cell overlap factor, CL is the confidence level described above, and N is the propagation distance exponent (typically, $2 < N < 4$, with 2 corresponding to free space propagation conditions). Equivalently, when all quantities are expressed in dB,

$$ABA = M_R + M_I + SNR_{\min} + F_R - F_V + G_V - G_R + 5N\left[\log_{10}\eta - \log_{10}(1-CL)\right].$$

A detailed derivation of this expression appears in the Appendix and follows the general approach outlined above.

Calculating the Required Adjacent Band Attenuation

To calculate the required adjacent band attenuation, we assume the following parameters:

Parameter	Value
M_R	13dB
M_I	19dB
$SNR_{\min}$	13dB
F_R	5dB
F_V	8dB
G_V	1.7dB
G_R	1.7dB
N	2, 4
η	2
CL	90%

The choice of parameter values can be explained as follows. The reception margin, M_R, is chosen with regard to *field propagation measurements* in suburban environments where the received signal power is described by a log-normal random process with about 10dB standard deviation. With this assumption, a receive margin of 13dB would place the cell boundary at a distance where reception occurs with 90% probability. Similarly, an interference margin, M_I, of 19dB places the interference boundary at a distance where the interference power is less than 6dB below the noise floor of the public safety receiver with 90% probability (6dB + 13dB = 19dB). The values for $SNR_{\min}$, F_R and F_V typify what can be achieved in practice without extreme effort. The values for G_V and G_R correspond to the antenna gains of short dipole antennas ($\lambda/10$). The overlap factor, η, assumes a large amount of overlap between cells.

Finally, the confidence level that no interference will occur, CL, is set to 90%. This level is consistent with propagation loss curves used by Motorola in its own interference analysis as described in a report that was presented to the National Coordination Committee.[1] Motorola's curves are based on field measurements of propagation loss. Based on these measurements, they claim a typical site isolation of 75dB, which is obtained with 90% confidence. In a similar fashion, the present analysis assumes a 90% confidence level that the calculated adjacent band attenuation will provide the specified protection in the field. In addition, it is important to note that, in our methodology, the boundary of an "interference zone" is defined as *the radius at which a public safety receiver experiences an interference power exceeding 6dB below the receiver noise floor with only 10% probability*. Thus, a public safety receiver that finds itself in an interference zone will not *necessarily* experience real interference; rather, it will have a modest *probability* of receiving interference, and only if it is operating near the boundary of its own coverage area. Thus, as befits a *conservative* analysis, this cascade of

[1] In particular, this information was contained in the draft FLEWUG report presented to the NCC on November 19, 1999.

probabilities implies that the real interference probability is significantly less than a simple reading of the numbers would indicate.

With the above assumptions, it is possible to compare the cases where $N = 2$ and $N = 4$ to see which propagation assumptions result in the more conservative specification for adjacent band attenuation. The result is summarized below:

	$N=2$	$N=4$
Required ABA	55dB	68dB

Significantly, the assumption that $N = 4$ is seen to be *conservative* with respect to determining the appropriate *ABA* requirement. As described in the Appendix, this result is physically reasonable because the greater acceleration in signal loss associated with fourth-law attenuation results in smaller cells for a given interference area, thereby implying an increased ABA requirement to achieve the same level of protection. In addition, this assumption, when combined with the use of margins to accommodate variations in the propagation environment, is a much more physical model that matches field measurements very well.

Note also that the expression for sideband attenuation does not include transmit power explicitly. This is due to the fact that the analysis assumes that cell sites are assigned to provide complete coverage at a particular transmit power. Thus, with this assumption, a decrease in transmit power implies a greater number of cells, with each cell having reduced interference and coverage areas. As a result, the *ratio* of interference and coverage areas does not change. It is this ratio, in part, that determines the confidence level that no interference will occur. Thus, although transmit power influences the distribution of the interference zones, it does not directly affect the overall confidence level.

For regulatory purposes, the expression for sideband attenuation given above corresponds to the transmit power spectral density by which cell sites are chosen. In the context of the FreeSpace proposal, this is the maximum power spectral density that can be used in the guard band, or 4mW/kHz (-24dBm/Hz). With 68dB of attenuation, the interference power produced at the input to the transmitter antenna in a 6.25kHz bandwidth would be –54dBm (-24dBm/Hz –68dB+10log(6250Hz) = -54dBm). We note that this power level is only 3dB less stringent than the level of –57dBm in a 6.25kHz bandwidth proposed by Motorola.

Of course, it is common sense that the required attenuation should be a function of transmit power. This guarantees that units operating at higher powers must meet more stringent requirements than those operating at lower powers. For this reason, we propose that the Commission adopt the following attenuation requirement for out-of-band emissions in a 6.25kHz bandwidth from units operating in the guard bands adjacent to public safety bands:

$$84 + 10\log_{10}(P_T),$$

where P_T is the transmit power into the transmitter antenna in watts. For absolute clarity, this equation should be interpreted to say that the out-of-band emissions power should fall below the transmit power by the stated attenuation, with the transmit power evaluated over the full bandwidth (e.g. the –26dB bandwidth) of the transmitter, and the out-of-band emissions power evaluated in a 6.25kHz bandwidth. Thus, a 1W unit operating under the FreeSpace proposal would have to produce no more than –54dBm interference power in a 6.25kHz bandwidth in the adjacent public safety band (30dBm – 84dB = -54dBm).

Although this rule may appear to be stringent, it is achievable within the context of a low power system and is thus consistent with the low power spectral density limits proposed by FreeSpace for use in the guard bands adjacent to public safety spectrum.

CONCLUSION

FreeSpace has outlined a method by which the appropriate adjacent band attenuation can be determined to protect neighboring public safety systems. The analysis is a conservative one that includes clear assumptions about what constitutes interference to a public safety receiver. Furthermore, the method presented includes margins based on field measurements to define coverage and interference boundaries that are conservatively defined to accommodate statistical variations in real-world propagation. FreeSpace's analysis shows that for guard band systems operating under the proposed power spectral density limits, an adjacent band attenuation of $84 + 10\log_{10}(P_T)$ in a 6.25kHz bandwidth is sufficient to confidently guarantee protection to public safety operations in the adjacent bands. This represents a *dramatic increase in attenuation* over the FCC's proposed rule of $43 + 10\log_{10}(P_T)$.

Although FreeSpace believes this level of attenuation will provide strong protection to public safety, it emphasizes that, as a licensee of the guard bands, it would of course comply with any technical rules, including out-of-band emissions limits, the FCC deems necessary to prevent interference to public safety systems.

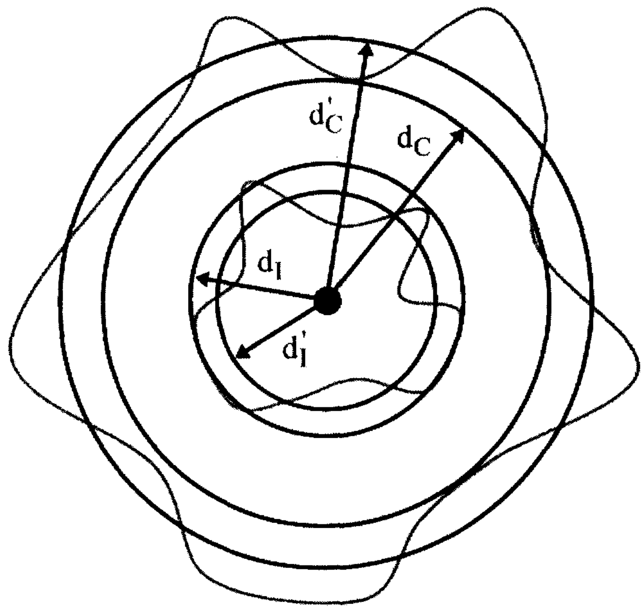

Figure 1. A typical cell. Not to scale.

Appendix: A Detailed Analysis of Adjacent Band Attenuation

Figure 1 illustrates a qualitative view of a typical radio cell. Although it is convenient to think of cells as having well-defined, circular boundaries, real cells have imprecise boundaries due to local variations in propagation conditions. These imprecise boundaries are illustrated as non-circular curves in the figure. Fortunately, these statistical variations are easily accommodated using margins in the analysis to determine a confidence level that a given boundary is contained within or without a specified radius. Suppose, for example, that the cell has an expected (i.e. average) radius give by d'_C and an expected interference radius of d'_I. With basic knowledge about the statistical distribution of received power, one can adopt margins that lead to the modified radii, d_C and d_I, which have a certain probability of respectively excluding or containing the real boundaries. For example, adopting an increased receiver margin results in a *reduction* in d_C because the reliability of reception improves as one moves towards the transmitter. In other words, for reliable reception it is important to be well *within* the average cell boundary. On the other hand, an increase in the interference margin results in an *increase* in d_I due to the fact that the probability of interference decreases as one moves away from the transmitter. In this case, to comfortably avoid interference, it is important to be well *outside* the average interference boundary.

With this understanding, it is possible to calculate the received power at radius d_C, and the interference power at radius d_I. By incorporating an adjacent band attenuation specification into the analysis, we can then relate these two quantities and develop a useful expression for the probability of interference.

A victim receiver at the boundary of the interference region accepts interference from adjacent band emissions of an interfering transmitter. The power spectral density of these emissions is attenuated below the transmit power spectral density of the interfering transmitter by the adjacent band attenuation, *ABA,* and the path loss from the transmitter, L_I. In addition, the bandwidth of the received interference power is determined by the effective noise bandwidth of the receiver, B_V. Thus, the received interference power is

$$P_I = \frac{(P_T / B_T) G_T G_V B_V}{L_I ABA},$$

where P_T is the transmitter power, B_T is the transmission bandwidth, G_T is the transmit antenna gain, G_V is the victim receiver antenna gain, B_V is the victim receiver bandwidth, L_I is the path loss to the victim receiver, and *ABA* is the adjacent band attenuation. The onset of interference occurs when the victim receives an interference power level that is below its own noise floor by a specified margin, M_I. Under this condition, the interference power is

$$P_I = \frac{F_V kTB_V}{M_I},$$

where F_V is the noise figure of the victim receiver, k is Boltzman's constant ($1.38*10^{-23}$), T is 290K, and M_I is the interference margin. Equating these two expressions and solving for L_I, yields an expression for the required path loss between transmitter and the victim receiver,

$$L_I = \frac{P_T G_T G_V M_I}{B_T ABA \cdot F_V kT}.$$

It is possible to perform a similar calculation at the cell boundary. At this distance, a receiver associated with the interfering transmitter receives a signal power, P_R, given by the path loss expression

$$P_R = \frac{P_T G_T G_R}{L_I L_{IC}},$$

where G_R is the receiver antenna gain, and L_{IC} is the additional path loss from the interference boundary to the cell boundary. Thus, the product $L_I L_{IC}$ is the *total* path loss from the transmitter to the cell boundary. For marginal reception, the received power must be above the receiver noise floor by the minimum acceptable signal-to-noise ratio, $SNR_{\min}$, times the required receiver margin, M_R. The received power at the cell boundary can thus be expressed as

$$P_R = M_R SNR_{\min} F_R kTB_R,$$

where F_R is the receiver noise figure, and B_R is the receiver bandwidth, which equals B_T. Equating these last two expressions, we can solve for the additional path loss from the interference boundary to the cell boundary, which yields

$$L_{IC} = \frac{P_T G_T G_R}{L_I M_R SNR_{\min} F_R kTB_R}.$$

Then, substituting the expression for L_I from above and canceling all of the common terms, results in a simple expression for the additional path loss,

$$L_{IC} = \frac{ABA}{M_I M_R SNR_{\min}} \frac{F_V}{F_R} \frac{G_R}{G_V}.$$

The additional path loss from the interference boundary to the cell boundary is directly related to the ratio of the distances from the transmitter to each boundary, and thus is also related to the areas of the cell and interference region. In particular,

$$L_{IC} = \left(\frac{d_C}{d_I}\right)^N = \left(\frac{A_C}{A_I}\right)^{N/2},$$

where A_C and A_I are the areas of the cell and interference region, respectively. Equating this expression with the previous one for L_{IC} leads to the following result

$$\left(\frac{A_C}{A_I}\right)^{N/2} = \frac{ABA}{M_I M_R SNR_{\min}} \frac{F_V}{F_R} \frac{G_R}{G_V}.$$

Note that this expression relates the ratio of the cell and interference areas to the required adjacent band attenuation in terms of relevant design quantities.

To determine the probability of interference based on this expression, it is necessary to extend it to accommodate multiple, overlapping cells. For this purpose, it is assumed that cells overlap with one another, but that the interference regions associated with the cells do *not* overlap. This is a *conservative* assumption that results in an increased probability of interference over what a single cell would provide. The degree of overlap is determined by an overlap factor, η, which is assumed to be greater than one. With overlap, each cell contributes an interference area A_I and a coverage area of A_C / η. The probability of interference is simply the ratio of these two. Thus, using the previous expression,

$$P(I) = 1 - CL = \frac{A_I}{(A_C / \eta)} = \eta \left[\frac{M_I M_R SNR_{\min}}{ABA} \frac{F_R}{F_V} \frac{G_V}{G_R}\right]^{2/N}.$$

This expression also introduces the parameter CL, which is the *confidence level that no interference will occur*. Finally, we can solve this expression for the required adjacent band attenuation, ABA, in terms of this confidence level, which yields

$$ABA = M_I M_R SNR_{\min} \frac{F_R}{F_V} \frac{G_V}{G_R} \left[\frac{\eta}{1-CL} \right]^{N/2} .$$

This equation expresses the required adjacent band attenuation in terms of specified margins, cell overlap, and the confidence level that no interference will occur, given assumptions about propagation, the minimum signal-to-noise ratio of the receivers in the interfering system and the receiver noise figures and antenna gains of both systems. It is comforting to note that, qualitatively, the required ABA increases as we increase the margins, increase the desired confidence level that no interference will occur, and increase the number of cells (i.e. increase η). When all quantities are expressed in dB, we have

$$ABA = M_R + M_I + SNR_{\min} + F_R - F_V + G_V - G_R + 5N\left[\log_{10}\eta - \log_{10}(1-CL)\right].$$

It is interesting to note that a larger N results in a more *stringent* SBA requirement, assuming that η is greater than unity and CL is positive and less than unity. Thus, it is *conservative* with respect to interference probabilities to assume fourth-law path loss conditions, where $N = 4$, over square-law path loss conditions, where $N = 2$. This is simply due to the fact that the increased attenuation rate associated with larger N implies that more cells will be required to cover a given area for a given radius of interference, thereby affording more opportunities for potential interference.